Description

Thin film piezoelectric resonator

The present invention relates to a thin film piezoelectric
resonator which can be produced using the methods of
micromechanics.

The resonant frequency of thin film piezoelectric resonators
in the frequency range above 500 MHz is indirectly
proportional to the layer thickness of the piezoelectric
layer. The carrier membrane and the bottom and cover
electrodes constitute an additional mass loading for the
resonator which effects a reduction in the resonant frequency.
The thickness fluctuations in all these layers determine the
range of manufacturing tolerances in which the resonant
frequency of a specimen resonator lies. Layer thickness
fluctuations of 5% are typical for sputtering processes in
microelectronics; 1% can be achieved with a considerable
outlay. Fluctuations occur both statistically from wafer to
wafer and systematically between the middle of the wafer and
the edge. The resonant frequencies of individual resonators
must exhibit an absolute accuracy of 0.5% for filters in the
GHz range.

A plurality of resonators must be connected in a ladder
configuration, lattice configuration or parallel configuration
for highly selected filters. The individual resonators must be
detuned specifically relative to one another in order to
achieve the desired filter characteristic. It is preferable
for reasons of cost to produce all the resonators of a filter
from a piezoelectric layer of constant thickness; frequency

tuning is performed by additive layers on the cover electrodes. An additional layer of different thickness must be produced for each resonant frequency which occurs. This requires in each case a deposition or an etching step, connected to a lithography step. In order to limit this outlay, it is customary to produce only filter topologies with the aid of which only two resonant frequencies are set.

The resonant frequency of thin film piezoelectric resonators can basically be trimmed by applying additional layers, as described above, but this necessitates expensive lithography. Material can be removed over the entire surface by laser trimming or ion-beam trimming, and this reduces the mass of the cover layer, although necessitating an expensive fabrication step at the end of the fabrication process. It is true that the resonant frequency can be shifted by connecting capacitors or applying a dc voltage, but the trimming range is comparatively narrow. The same holds for thermal trimming by heating up the resonator.

It is the object of the present invention to specify a thin film piezoelectric resonator which can be set to a prescribed resonant frequency using simple means and with high accuracy. It is also to be specified how a plurality of resonant frequencies can be set in a simple way.

This object is achieved with the aid of the thin film piezoelectric resonator having the features of claim 1 and, respectively, with the aid of the arrangement having the features of claim 6. Refinements follow from the dependent claims.

In the layer of the cover electrode, or in an additional layer specifically applied therefor, the thin film piezoelectric

resonator according to the invention is provided with holes, preferably produced lithographically, or similar structures, which have a mean spacing from one another which is smaller than the acoustic wavelength provided during operation of the component. These structures are preferably distributed with a uniformity sufficient to effect a uniform change in the mass of the layer per area (area density), thus producing a specific setting of the resonant frequency/frequencies, and are preferably, on the other hand, distributed so irregularly that defraction effects are avoided.

A more precise description of the thin film piezoelectric resonator according to the invention follows with reference to Figs. 1 to 3.

Fig. 1 shows an exemplary embodiment of a resonator according to the invention, in cross section.

Fig. 2 shows the detail marked in Fig. 1 in an enlargement.

Fig. 3 shows the structure of the top layer in plan view.

Fig. 1 shows an example of a resonator according to the invention, in cross section. Located on a substrate 1 is a carrier film 2, which is preferably polysilicon and below which a cavity 4 in an auxiliary layer 3, for example made from oxide, is located in the region of a layer structure provided as resonator. The cavity typically has the illustrated dimension of approximately 200 μm. Located on the carrier film 2 is the layer structure of the resonator, comprising a lower electrode layer 5 provided for the bottom electrode, a piezoelectric layer 6, and an upper electrode layer 7 provided for the cover electrode. The electrode layers 5, 7 are preferably metal, and the piezoelectric layer 6 is, for example, AlN, ZnO or PZT ceramic (PbZrTi). This layer

structure overall typically has the illustrated thickness of approximately 5 µm.

According to the invention, etching structures which are preferably produced lithographically are present in the upper electrode 7 or in a further layer applied thereto and denoted below as additional layer 8; these structures fix the resonant frequency or a plurality of different resonant frequencies in the way provided. In the example illustrated in Fig. 1, these etching structures are located in an additional layer 8.

The detail marked in Fig. 1 with a circle 9 is shown in Fig. 2 in an enlargement in which it is possible to see the structure of the additional layer 8 on the upper electrode layer 7 and on the piezoelectric layer 6. The additional layer 8 is perforated in this example by a multiplicity of holes 10. The effective mass loading of the resonator, and thus the resonant frequency, are specifically set via the density of the distribution of these holes 10. For a frequency of 1 GHz, the acoustic wavelength of current thin film piezoelectric materials is in the range from 5 µm to 10 µm. If the holes of the perforation and their spacing are substantially smaller than the acoustic wavelength, the perforation is fuzzy for the acoustic wave and therefore does not scatter the wave; the perforation acts on the wave as a change in the mean density of the material. A further advantage achieved is to scatter higher modes of the resonator at the holes, thereby reducing the undesired influence of these modes on the filter characteristic.

Fig. 3 shows the additional layer 8 in plan view, such that the position of the holes 10 (approximately square here) can be seen. Instead of individual holes in the additional layer 8, it is also possible to have contiguous interspaces which,

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for example, occupy the entire region between the square regions 10 illustrated in Fig. 3. These regions then form islands 10 made from the material of the additional layer 8. The essence of the structure present is that the cutout regions of the structured layer and/or the remaining islands are arranged such that the desired setting of the resonant frequency is achieved. If the structure is directly present in the upper electrode layer 7, it is advisable to leave all of this electrode layer 7 except for holes of approximately the size and arrangement as illustrated in Fig. 3 (holes 10).

When the resonator is being produced, fluctuations in the layer thickness can be evened out by specific and, if appropriate, (for example through the use of steppers) spatially varying overexposure or underexposure in the lithography. An arbitrary number of resonant frequencies can be implemented on the same chip without additional outlay with the aid of a plurality of resonators of appropriate design. During production, this requires merely a change in the spacing and the size of the holes in the mask used for the lithography. In particular, filters with parallel resonators and filter banks for separating frequency bands can be implemented easily in this way.